

Dynamic Positioning Reliability Index (DP-RI) and Offline Forecasting of DP-RI during Complex Marine Operations.

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ABSTRACT

The Dynamic Positioning (DP) System is a complex system with significant levels of integration between many sub-systems to perform diverse control functions. The extent of information managed by each sub-system is enormous. The complex level of integration between sub-systems creates more possible failure scenarios. A systematic analysis of all failure scenarios is tedious and for an operator to handle any such catastrophic situation is breath taking. There are many accidents where a failure in a DP system has resulted in fatalities and environmental pollution. Therefore, reliability assessment of a DP system is critical for safe and efficient operation of marine and offshore vessels.

Traditionally, the reliability of a DP system is assessed during the design stage by methodologies such as Failure Mode Effects and Analysis (FMEA), Proving Trials, Hardware In-the Loop (HIL) testing, Site-Specific Risk Analysis, DP capability Analysis and during operation by annual trials to verify functionality. All these methods are time consuming, involving a lot of human effort and notably no analysis of previous accidents are indicated in the reliability assessment. This imposes in-built uncertainty and risk in DP system during operation.

In this paper, a new concept of Dynamic Positioning Reliability Index (DP-RI) is introduced and a state-of-the-art advisory decision making tool is proposed. This tool is developed based on information from various sources including Offshore Reliability Data (OREDA), International Marine Contractors Association (IMCA) Accident database, DP vendor equipment failure databases, DP System supplier's manuals, previous system level FMEA and HIL testing results, Site specific risk analysis documents, Project design specification and Operator's operational experiences. Thus, DP-RI addresses the pitfalls of existing reliability assessment methods and will be an efficient tool in reducing the number of DP-related accidents.

INTRODUCTION

In today's world of challenging environments where offshore and marine vessels operate with high precision, within meters of each other with no options for mooring, the need for safe and reliable positioning is particularly important to prevent injury to people and damage to property. In this high pressure and intense environment, the potential for risk and probability of accidents has increased. The consequences of loss of position can be severe, so the need for reliable and safe systems is greater than ever. The Dynamic Positioning (DP) system is the only viable option. DP systems have been developing since the 1960's and as the oil and gas industry operates in deeper and deeper waters, vessels without DP cease to be an option. For vessels with DP systems, the most critical safety incidents are loss of position and/or heading. Therefore, it is necessary to design DP systems to be fault tolerant and fault resistant systems [1]. This is to ensure that the complex vessel, operating in a harsh environment, could be safer, reliable and efficient.

Figure.1 shows the vessel's six Degrees of Freedom (DOF) which includes translatory motions: surge, sway and heave and angular motions roll, pitch and yaw. These motions contribute to the dynamics experienced by a vessel operating in a deep-water environment. The six DOF equations of motion representing the kinetic and kinematics of a DP vessel can be represented as Equation (1) [2]

$$M\dot{v} + C(v)v + D(v)v + g(\eta) = \tau + g_o + w \quad (1)$$

Where M - system inertia matrix (including added mass)
 $C(v)$ - Coriolis-centripetal matrix (including added mass)
 $D(v)$ - Damping matrix
 $g(\eta)$ - vector of gravitational/buoyancy forces and moments
 τ - vector of control inputs
 g_o - vector used for pre-trimming (ballast control)
 w - vector of environmental disturbances (wind, waves and currents)

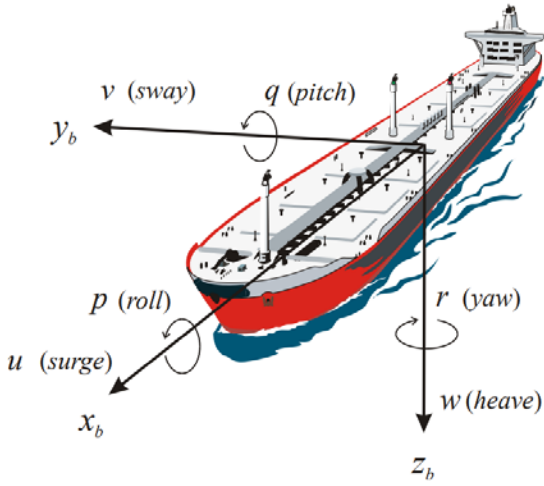


Figure 1. Dynamics of Vessel with Six DOF [3]

The dynamics of the vessel presented in Equation (1) also represent the physical properties of the system which are further used for control system design. The advanced DP system, by design, is itself a complex system with significant levels of integration between many sub-systems to perform diverse control functions. In addition, the external environment affects the overall performance. Therefore, it is necessary to perform reliability assessment and risk analysis of the complex system to identify the factors contributing to loss of position and/or heading or, worst case design failure [4].

The major phases of the DP life-cycle include design, construction, commissioning, sea-trials and operation. In all of these phases, the design evolves and changes are implemented for safe, reliable and efficient operation. Historically several traditional reliability assessment methods have been implemented in different phases for improving the design of the system. However, they have not made a significant contribution in the prevention of all the accidents or reducing the number of accidents based on the analysis of the accident database report from IMCA [5]. In addition, the traditional reliability assessment methods have not demonstrated their ability to provide clear information on faults and provide appropriate solutions during operation.



Figure 2. Life cycle of a DP system

The analysis of existing reliability assessment methods revealed key drawbacks which are listed below:

- Lack of user knowledge and experience from previous incidents / accidents.
- Lack of consideration of interdependencies between sub-systems.
- Lack of consideration of the relatively short reaction time available for an operator to take corrective actions.

In this paper a new concept of DP-RI is introduced. This is a qualitative and quantitative representation of reliability of the system.

To date, such a method has never been used for Risk Analysis or analyzing the reliability of a DP system during operation. This is a qualitative and quantitative representation of the reliability of the system. The biggest break-through is that this tool uses the industry experience from previous accidents / incidents and industry experts' inputs during operation. In addition, a state-of-the-art advisory decision making tool is proposed which is based on a predictive analytics concept

This is based on a machine learning algorithm, Extreme Learning Machine (ELM) for predicting the DP-RI value based on the input from an operator and the plan of the operation for simulation analysis. It clearly bridges the gaps in existing reliability assessment and will aid operators in preventing accidents.

LITERATURE REVIEW

The levels of complexity and sophistication of DP systems have developed incredibly over the last few decades. The advancement in DP has undoubtedly been instrumental in the creation of a new design for vessels and, at the same time, many new vessel types have been introduced to the market [6].

The overall DP system comprises different equipment and systems that directly and indirectly affect the position keeping / heading of the vessel. The reliability of DP Systems directly depends on various system aspects such as equipment selection, design, architecture, functionality, integration, verification, codes and standards, rules and regulations [7].

The reliability of DP systems depends on the redundancy of the equipment, so that a sudden failure of one item of equipment or an inadvertent act will not cause an unexpected loss of vessel position and/or heading. In addition, the reliability indirectly depends upon third party DP design consultation, FMEA, HIL, operational planning and procedures, training of operating personnel, company safety policies, local authority and government rules and regulations. [8]

The different types of traditional reliability assessment of DP systems in different phases of the life cycle are listed below: [8] [9]

- FMEA (System Level Independent FMEA)
- DP capability Analysis
- HIL testing
- Site Specific Risk Analysis
- Operational Procedure and Maintenance System

All the above-mentioned methods are governed by industry rules, standards, recommended practices, guidelines and regulations. Depending on vessel operator preference and vessel specific application either one or more of the traditional reliability assessment methods may be used to verify the DP system design.

Most of the traditional reliability assessment methods place more importance on the redundancy of the design due to misinterpretation of rules and standards. Often the reliability is determined by redundancy level in the system which is incorrect as those are completely different concepts and not synonymous [7].

Table 1. DP system Equipment Class by IMO

Equipment Class	Definition of Worst-Case Failure Mode
Equipment Class 1	No Redundancy. Loss of position may occur in the event of a single fault
Equipment Class 2	Redundancy of all active components Loss of position will not to occur in the event of a single fault in any active component or system. Normally static components will not be considered to fail where adequate protection from damage is demonstrated, reliability is to the satisfaction of the administration. Single Failure criteria include: <ul style="list-style-type: none"> Any active component or system (generators, thrusters, switchboards, remote control valves etc.) Any normally static component (cables, pipes, manual valves, etc.) which are not properly documented with respect to protection and reliability
Equipment Class 3	Redundancy and physical separation of all components.

The DP system requirement has been divided into equipment classes 1, 2 and 3 based on the system reliability in “IMO MSC circular 645 Guidelines for vessels with dynamic positioning systems” by the International Maritime Organization (IMO) [4], as presented in Table 1.

All major classification societies have prepared rules, standards and guidance for DP systems, based on the IMO three levels of equipment classes, with minor differences. Similarly, most of the traditional reliability assessment is performed during the design stage but these do not provide true representation of reliability during DP operation.

System Level Independent FMEA: This is a systematic method to analyze the system by identifying the potential failure modes, their causes and effects on the overall system [10]. The assessment involves two phases i.e. Desktop FMEA and Proving trial. The desktop FMEA of the DP system is limited only to hardware (HW) parts and the Proving trial tests only part of the input-output (IO) layer in the control system. The guide from IMCA doesn’t not provide any guidance for FMEA on how to use the experience from previous DP failure incidents.

DP capability Analysis: The analysis defines the vessel’s station-keeping ability under given environmental and operational conditions. The IMCA specification is quite basic allowing the analysis to be computed with environmental forces and non-vessel-specific co-efficient. In addition, thruster force from a generic rule-of-thumb can be considered without including the specification of the DP control system and thruster allocation.

HIL testing: This testing involves validation of the control logic part and ensures that the control system performance is satisfactory at all layers of software. Experience has shown that a lack of understanding of the interfaces and shared functionality between various systems results in the vessel design deviating from class rules [11]. All the testing related to HIL is simulation based and, in real time, the dynamics and transients of the system could be completely different.

Site Specific Risk Analysis: Due to increase in awareness created by DP related accidents, new site specific risk analysis techniques have been introduced to perform reliability assessment. The tools include Critical Activity Mode of Operation (CAMO), Task Appropriate Mode (TAM), Activity Specific Operation Guidelines (ASOG) and Well Specific Operation Guidelines (WSOG) [12].

Often these guidelines lack structured operational limits criteria which are critical for incident free and efficient DP operation.

Operational Documentation and Maintenance System: As per IMO circular 645 [4], the operational document is listed as a key document. The vessel specific DP operation manual is the most important document for providing guidelines to the operator during operation and this is developed during the design phase. Often there is a lack of consistency and standardization as only certain classification societies have requirements defined for the DP operation manual.

The gap analysis on traditional reliability assessment revealed many drawbacks as listed below:

- The experience from the previous accident database was not taken into consideration while performing reliability assessment for new vessels.
- There is always inconsistency in the reliability assessment of similar vessels performed by different independent consultants.
- The reports produced through reliability assessment contain too much irrelevant information and highlight only the possible failure modes.
- There are no clear solutions and guidelines on the steps to be taken in the case of failure.
- Lack of visibility on Inter-Dependency of sub-systems.
- No consideration of relatively small response time for operators to react and prevent accidents.

These critical drawbacks are identified from the list as shown in Figure 3.

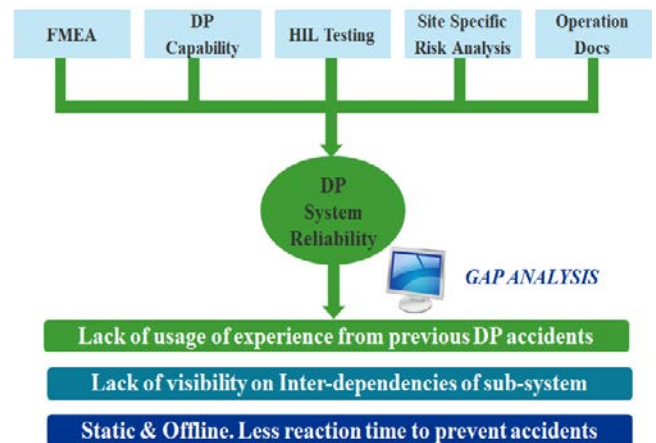


Figure 3. Existing DP Reliability Assessment – Gap Analysis

This above gap analysis clearly highlights the need for a new approach towards reliability assessment of DP systems. The proposed concept of DP-RI addresses these gaps and its primary focus is towards bridging these gaps. The concept is built upon a large amount of real time data available across the industry combined with experts' knowledge for finding the most appropriate solution. This opens up an opportunity to address the existing problems in a new direction.

DYNAMIC POSITIONING RELIABILITY INDEX (DP-RI) CONCEPT

The DP-RI concept is proposed to aid an operator with quantitative and qualitative representations of reliability of DP systems during complex marine operations. This concept is not a replacement method or an alternative solution for the current reliability assessment; it will enhance the existing reliability assessment results by combining them with a newly developed database and industry experts' knowledge. The DP system is classified into various sub-systems using big data analysis and a correlation method. Each of the sub-systems has been given a weighting factor and a Reliability Index (RI) is calculated based on the DP class type, configuration and mode of operation.

Data Sources

The Marine, Offshore and Oil & Gas sectors have realized the potential of data that they have harvested over the years and started leveraging on the knowledge acquired from this data for key decision making during operations. This technology breakthrough happened when condition based monitoring was accepted as an industry wide practice in Oil & Gas. In the context of the DP system, which has been in the field for more than 60 years, there was a huge volume of data available which could have been used in a better way. For the proposed DP-RI concept, the data was collected from different resources and, based on the category of the data, six different databases have been created. Some of the databases were created using publicly available data and some were created using confidential and privately owned data obtained from consulting a company or vendor. The new databases thus created are listed as below:

- FMEA Database: 30 Years of data from DNV GL and Noble Denton Experience

- IMCA Accident Database [5]: 35 Years of data collected from publications of the IMCA.
- OREDA Database [13]: More than 50 years of data collected and maintained by SINTEF and oil companies.
- HIL Testing Results Database: 15 Years of testing results data from DNV GL and Marine Cybernetics
- DP capability Plot ERN Database: 30 Years of data from DNV GL.
- Manufacturer Equipment Failure Database: 30 Years of data from DP system vendors and DNV GL.

Big Data DP system classification

In general, the term DP system means the complete installation necessary for dynamically positioning a vessel, consisting of following sub-systems [4]:

- Power System
- Thrusters / Propulsion System
- DP control system

Data analysis was performed on the available databases using big data tools including PowerBI and R Script and this revealed correlations between different sub-systems. Based on the obtained correlations, the DP system is divided into the following sub-systems in the DP-RI concept [1] [5]:

- Power System
- Thrusters / Propulsion System
- DP control system
- Reference System
- Electrical System
- Environment System
- Operator / Human Error

DP sub-system weighting distribution

DP sub-systems interact with each other continuously and exchange information during operation. Based on the analysis of the databases, different sub-systems contribute distinctly to the overall vessel performance. Therefore, for calculating the DP-RI, a unique weighting factor is assigned to different sub-systems based on information from the databases, correlation analysis and industry experts like vendor control system specialists, design engineers, FMEA experts and vessel operators.

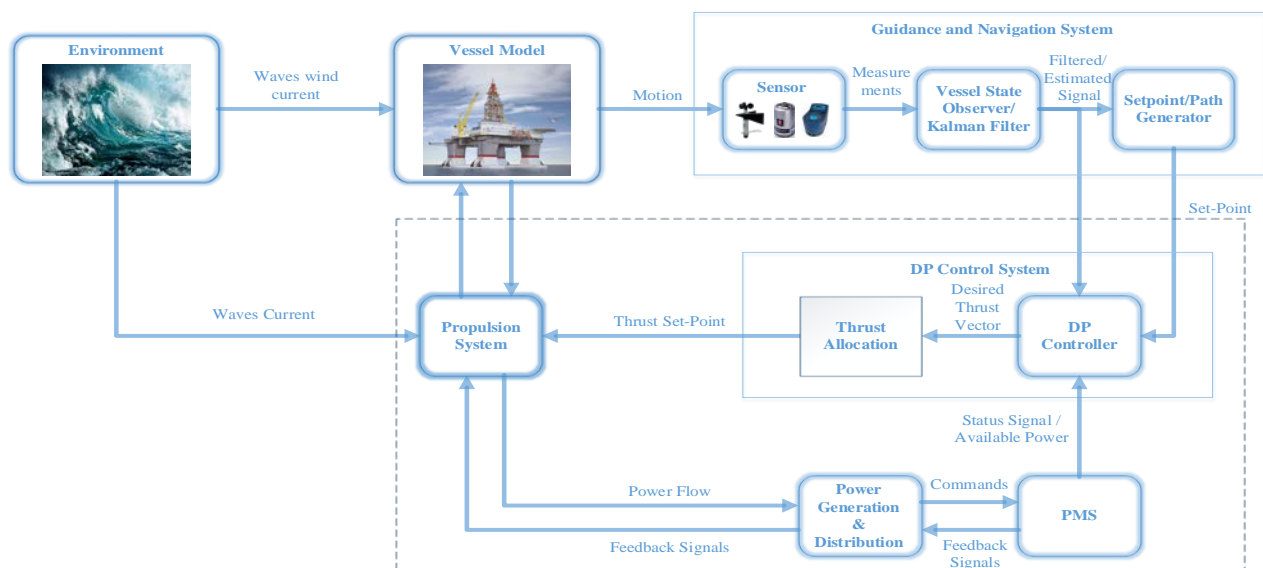


Figure 4. Dynamic Positioning System – Interfaces and sub-systems

The assigned weighting distribution for each sub-system is indicated in Table 2 [1] [5].

Table 2. DP sub-systems weighting distribution

SNo	Sub-System description	Weighting
1	Reference System (A1)	20
2	DP Control System (A2)	10
3	Thruster / Propulsion System (A3)	15
4	Power System (A4)	10
5	Electrical System (A5)	5
6	Environment System (A6)	10
7	Operator / Human Error (A7)	30

Reliability Index Computation (DP-RI Formulation)

The reliability Index is calculated based on the reliability of each sub-system and their weighted contribution to the overall vessel DP performance. The DP class type, system configuration and mode of operation are taken into consideration for accurate representation of DP-RI. With careful analysis of the databases, consideration of the availability of redundant systems, experience, knowledge from previous accidents and input from industry experts (consultants, designers, engineers, operators etc.) the RI is represented for normal and fault conditions as shown in the below equations.

$$RI(\text{condition}, \text{type}) = ((0.20 * A1 + 0.10 * A2 + 0.15 * A3 + 0.10 * A4 + 0.05 * A5 + 0.10 * A6 + 0.30 * A6) * K) \quad (2)$$

where

$$K = \begin{cases} 1 & \text{if condition} = \text{normal}, \text{type} = \text{all types} \\ 0.8 & \text{if condition} = \text{faulty}, \text{type} = \text{DP3} \\ 0.6 & \text{if condition} = \text{faulty}, \text{type} = \text{DP2} \\ 0.3 & \text{if condition} = \text{faulty}, \text{type} = \text{DP1} \end{cases}$$

OFFLINE FORECASTING / PREDICTIVE ANALYTICS OF DP-RI USING SIMULATION TOOL

In this section, the DP-RI tool is presented which uses predictive analytic techniques for offline forecasting of DP system reliability. The DP-RI tool is developed with a frontend GUI and backend mathematical modelling. Scilab software using python programming is used for mathematical modelling and predictive analytics. Scilab is an open software for numerical computation, simulations, control system design & analysis, optimization and statistics. The DP-RI tool consists of a graphical user interface where the operator would be able to key in the status of sub-systems at any given time and estimate the reliability of the DP system. The data sets obtained from the databases are used as input to a machine learning algorithm to perform predictive analytics. The overall DP-RI architecture and framework is shown in Figure 5. The tool development and information flow for operator decisions is presented in Figure 6.

Datasets

The datasets comprise information from different database sources as mentioned in the Data Sources section. The datasets presented are collected from different types of vessels. to make sure that different application vessels are covered and, at the same time, uncertainties are minimized. The data sets are prepared to suit the DP-RI tool application. The data used for training of the machine learning algorithm is obtained from 50 vessels with 3 different DP class type configurations and 5 different operation modes totaling 1000 samples. Out of 1000 samples it is categorized into two different groups of datasets as below:

- **Training Datasets:** This set of samples are used to train the machine learning algorithm and 75% of total sample dataset created are used. During selection, it is made sure the variety of data used covered as much as different combination of real time scenario.
- **Testing Datasets:** It is used to test the performance of machine learning algorithm and 25% of total sample dataset created are used. These datasets are completely different from training dataset to ensure that algorithm is properly trained and predict the correct output.

Machine Learning Algorithm: Extreme Learning Machine (ELM)

ELM provides a unified solution for a generalized feedforward network. In ELM, the input parameters, hidden node parameters are randomly generated and output weights are computed analytically [14] The unique feature of ELM is high accuracy, least user intervention and real-time learning.

The ELM algorithm can be represented by the following steps:.

Step 1: Define training dataset and choose the number of hidden neurons per incremental-decremental procedure.
Training Data sets: $\{(u^1, v^1), \dots, (u^t, v^t)\}$

Step 2: For each neuron, choose the Gaussian center and their width randomly
Gaussian Centre: μ_k and $k = 1, \dots, K$
Hidden neuron width: σ_k and $k = 1, \dots, K$

Step 3: Calculate the hidden layer output matrix (H) per the ELM algorithm equation.

$$H(U, \mu, \sigma) = \begin{pmatrix} h_1^1(u^1, \mu_1, \sigma_1) & \dots & h_1^L(u^L, \mu_1, \sigma_1) \\ \vdots & \ddots & \vdots \\ h_k^1(u^1, \mu_k, \sigma_k) & \dots & h_k^L(u^L, \mu_k, \sigma_k) \end{pmatrix} \quad (3)$$

Step 4: Estimate the optimal output weight
Optimal Output Weight: $W = VH^T$

For any data set with “L” training samples, the regression problem is defined to approximate the functional relationship as accurately as possible. This will ensure the output predictions for the new sample are achieved with greater accuracy than would be achieved with statistical and mathematical models. An ELM with “m” input neurons and “n” output neurons and “K” hidden neurons was designed for this problem.

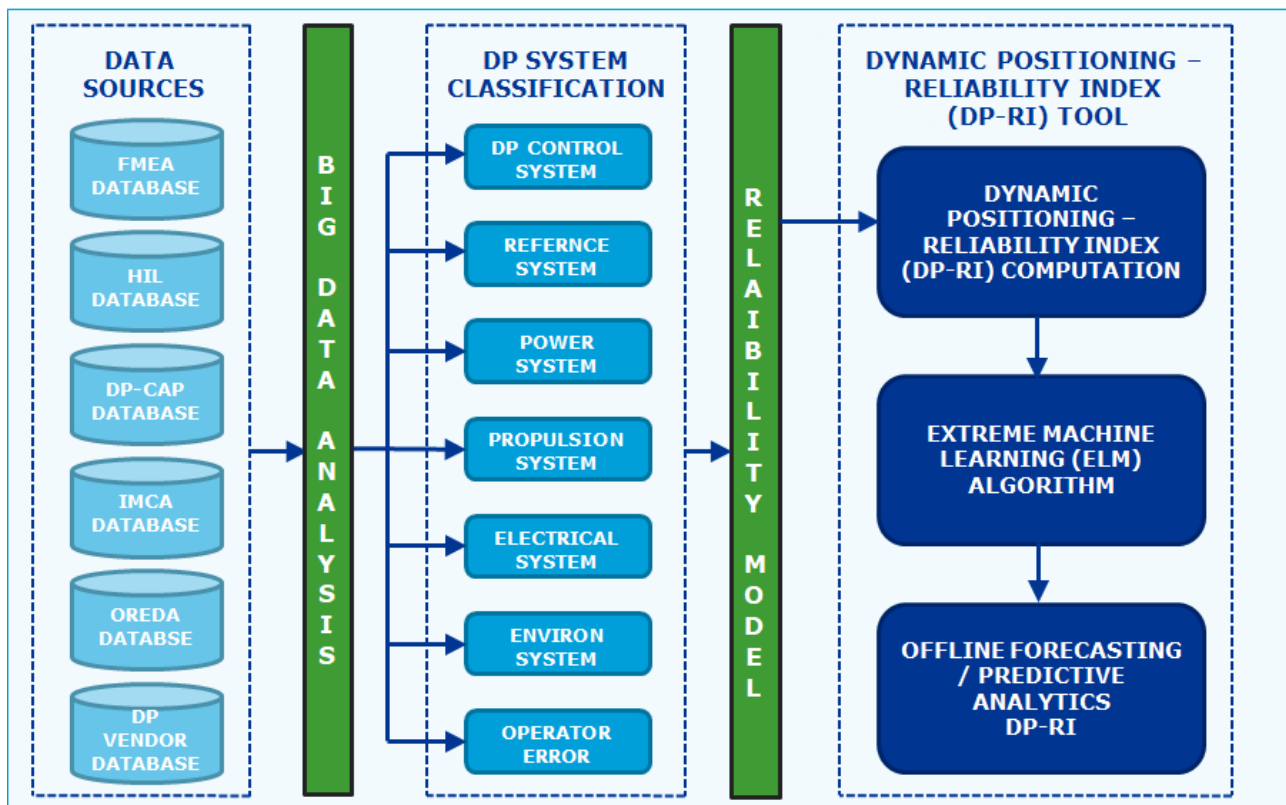


Figure 5. Dynamic Positioning Reliability Index (DP-RI) Architecture and Framework

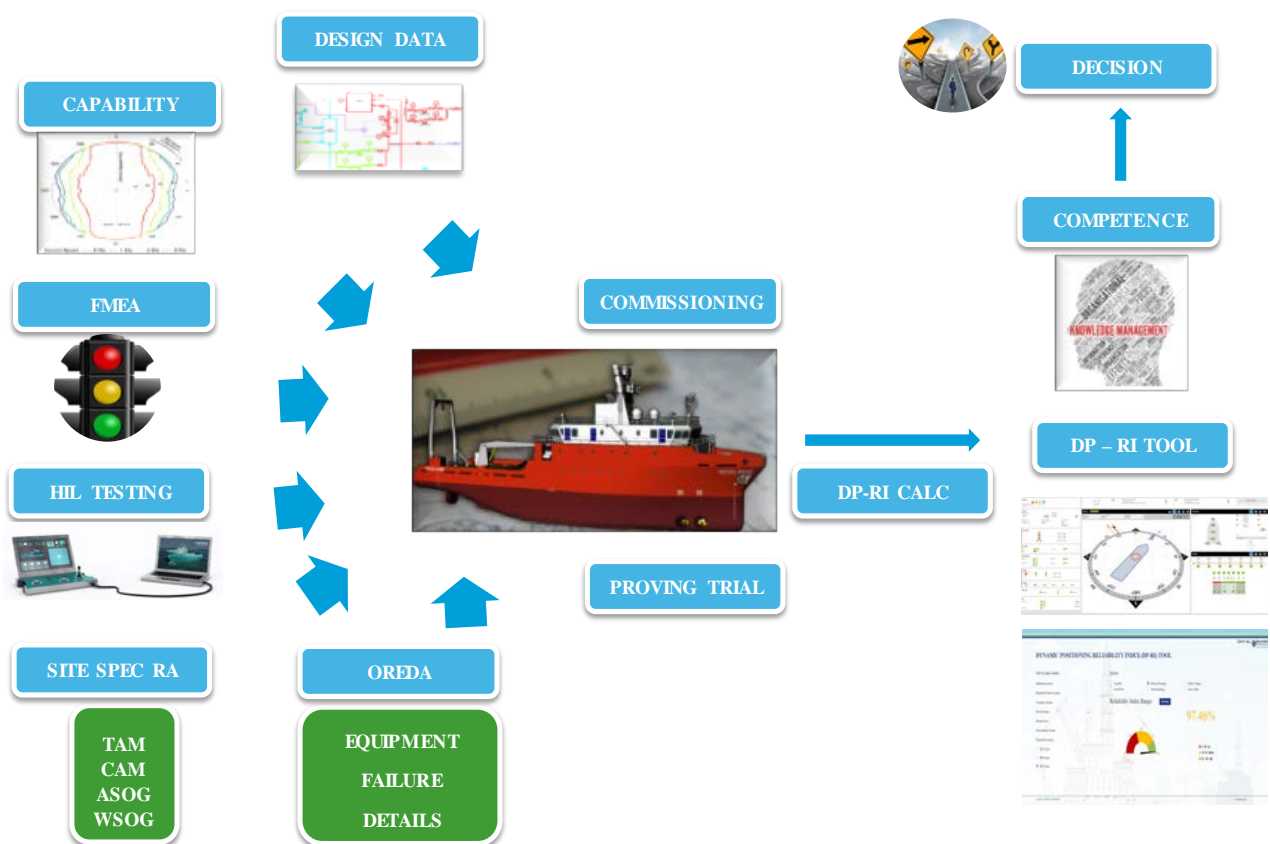


Figure 6. Dynamic Positioning Reliability Index (DP-RI) Tool Overview

The response of k-th hidden neuron for the “t-th” sample is:

$$h_k^t(u^t, \mu_k, \sigma_k) = \exp - \left(\frac{(u^t - \mu_k)^T (u^t - \mu_k)}{2 \sigma_k^2} \right) \quad (4)$$

$k=1, \dots, K$.

From previous studies [15] [16], it is evident that even for small data sets the performance of ELM is independent of activation functional test. Thus, this paper presents a unified approach to estimate the Reliability Index of a Dynamic Positioning system independent of the type of vessel, DP class type, vessel configuration and mode of operation.

Performance results

In this section, the performance results of the ELM in the prediction of Reliability Index of DP system are presented. The performance of ELM is compared with two other state-of-the-art machine learning algorithms, Support Vector Regression (SVR) [17] and Back-Propagation (BP) [18]. The number of hidden neurons and support vectors were selected using similar constructive-destructive procedures [20]. The Root Mean Square Error (RMSE) and Correlation Coefficient (CC) were chosen as performance indices.

The RSME represents the prediction accuracy and it is defined by

$$RSME = \sqrt{\frac{1}{L} \sum_{j=1}^L (V_j - \hat{V}_j)^2} \quad (5)$$

The CC represents the linear dependency of two random variables. The linear dependency is **strong** if CC is greater than 0.8 and **weak** if CC is less than 0.5.

$$CC = \frac{Con(V, \hat{V})}{\sqrt{Var(V)Var(\hat{V})}} \quad (6)$$

Table 3. Performance Analysis Results

SNO	MACHINE LEARNING	RMSE	CC
1	Extreme Learning Machine	0.1852	0.9518
2	Support Vector Regression	0.3078	0.8895
3	Back Propagation	0.2578	0.8789

The ELM network was trained to predict the DP-RI. It was trained using the data sets prepared from the FMEA database, HIL database, IMCA accident database, DP capability plots, OREDA database and Manufacturer Equipment Failure database of more than 50 vessels.

The generalization and forecasting prediction ability of the ELM were tested using a statistical approach and real operational conditions. The tool’s ability to match the real-life scenarios proved its efficiency and performance are within the acceptable limits. Thus, the DP-RI tool can be used as a training tool, helping operators to understand the reliability of a DP system from a more practical aspect.

RESULTS AND DISCUSSION

The results of the tool were found to be more accurate than SVR and BP when compared with real cases. The prediction and computations are effortless and the method is universal when compared to the statistical model based approaches. The operator can easily understand the exact reliability of a DP system without needing to refer to too much paper documentation generated from traditional reliability assessment studies. The tool’s ability to predict the reliability is accurate as proved through some real-life incident scenarios from the IMCA accident database. Two accident scenarios were extracted from the IMCA accident database [5] and the results of testing with the proposed tool are presented in Appendix 1. These two cases occurred in two different vessels, at different operating conditions, from two different years.

For *Case 1*, in the real scenario the vessel was in DP with 4 thrusters online, 4 generators online with the bus tie open, 3 gyros online, 2 MRU (Motion Reference Units) online, 2 wind sensors online, 3 DGNSS (Differential Global Navigation Sensor Systems) online, 1 HPR (Hydro acoustic Positioning Reference System) online and operating in “Follow Target” mode performing trenching operations. Due to a DP control system computer failure, the vessel moved 24 meters until the vessel mode changed to fixed position and vessel stabilized. The trencher was dragged across the sea-bed leading to a critical incident.

In the DP-RI tool, a simulation was performed of the same case and the predicted Reliability Index is 65%. This clearly indicates that the reliability of the DP system has reduced by more than 33%. At this situation, it is the responsibility of the operator to make sure that the DP computer system failure is addressed. The action should have mitigated the accident, thereby preventing a position shift.

For *Case 2* in the real scenario, the vessel was in DP with 6 thrusters online, 4 generators online with the bus tie open, 3 gyros online, 3 MRU, 2 wind sensors, 2 DGNSS online and operating in Station Keeping mode performing drilling operations. The 2 DGNSS signals were lost, resulting in drifting of the vessel followed by suspension of the drill string operation. The operator realized that during the drilling operation the third independent position reference signal was not available and changed the mode from station keeping to manual mode in order to stabilize the vessel to a desired position.

In the DP-RI tool, a simulation was performed of the same case with similar setup and it was found that the reliability of the DP system was reduced by 50% due to the fact that the third position reference system was not available during drilling operations. Thus, with this analysis the operator could have been alerted that drilling operation with only DGNSS as position reference is not recommended. In this way, the tool could have acted as an advisory tool and prompted the operator to enable the third position reference system before enabling the drilling operation.

Thus, the simulation results of this tool show that the reliability value provided to the operator with the necessary information would prevent the loss of position and/or heading from a failure scenario. The 2 cases presented above clearly demonstrate the ability of the DP-RI tool and its effectiveness.

CONCLUSION

In this paper, the concept of DP-RI has been presented as an offline forecasting / prediction DP-RI advisory tool. This tool calculates the reliability of the DP system based on the input from the operator for simulation purposes. It helps the operator to simulate different operating conditions and the status of sub-systems to pre-determine the reliability of the DP system and prepare for any specific operating condition.

This simulation could help an operator to get insights of the reliability of the DP system under different fault conditions and help to generate solutions even for a worst-case failure scenario.

DP-RI will clearly address the gaps found in the traditional reliability assessment methods of a DP system. It proves its effectiveness by its following three unique features

- Knowledge based tool together with of experience from previous incidents / accidents.
- Consideration on interdependencies between sub-systems and impacts on other systems when a failure in one system happens.
- Reduction in the time spent by an operator on failure scenario and aids in preventing accidents.

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APPENDIX: I

CASE STUDY NO: 1

UNEXPECTED MOVEMENT OF VESSEL TO 24M AWAY FROM TARGET IN “FOLLOW TARGET” MODE

IMCA Accident Database Case 1460: Vessel was in “Follow Target” Mode and unexpectedly drifted 24 meter away from the target

Primary Cause as reported in IMCA: Malfunction of DP Operator System Software was identified.

Secondary Cause as reported in IMCA: Human Error was identified. As there was ample of time for operator to stabilize the vessel to a stationary position with the help of DP system and trenching could have been stopped eventually. The mode could have changed by DP operator and prevented the movement of vessel from the target.

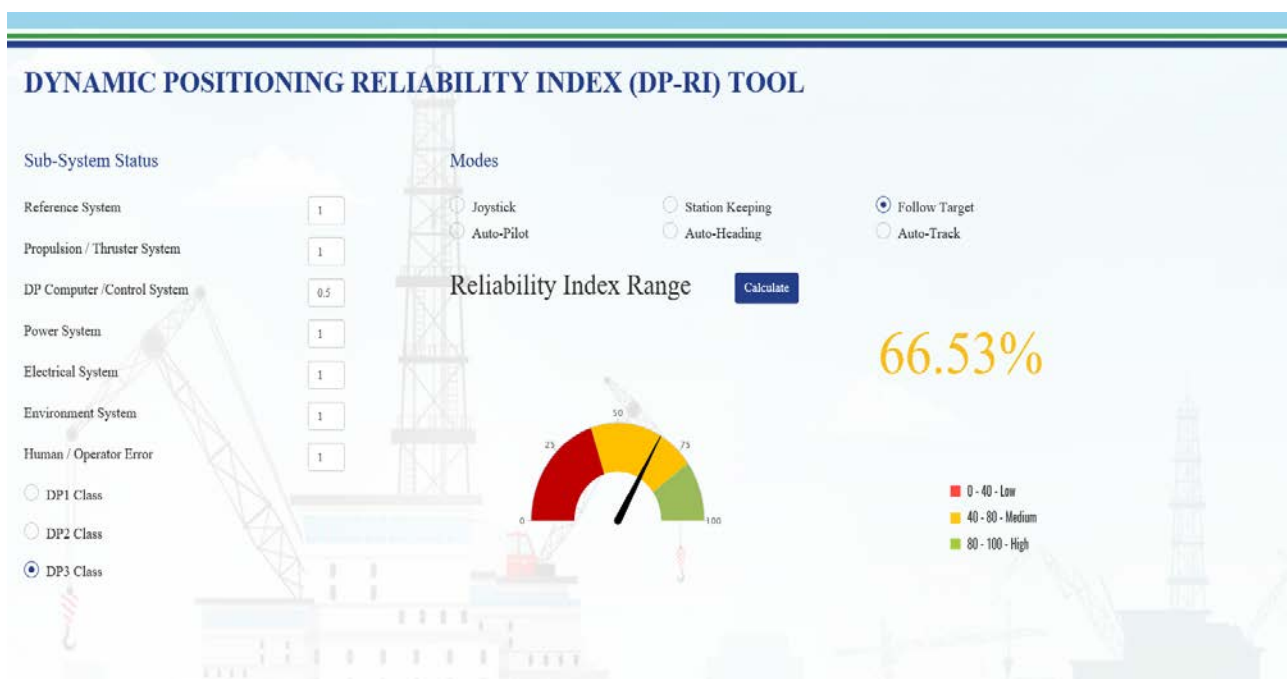
Actual Incident Scenario: Due to a software malfunction in the DP operator station, the vessel started to drift away 24 m from target position. The situation was not alerted to the operator by the alarm annunciation system. Thus, the operator was unaware of the situation. In the reliability assessment studies performed during the basic design process, such a scenario was not studied and it left the operator with no information on how to handle such failures.

Upon a failure situation during operation, the operator would normally refer to FMEA, Operational Procedure and Site-specific risk analysis documents to identify the best solution that can be effective to resolve the problem. However, some failures of such extent are not captured in any of the above-mentioned documents, thereby leaving the DP operator without any efficient tool for decision making in critical situations.

PROPOSED DP-RI DECISION MAKING TOOL:

Situation Awareness: DP-RI tool is developed using relevant databases of actual accidents from IMCA, previous industry FMEA database, HIL testing findings, DP capability assessment report etc. This ensures that all possible failures are captured in this tool. This will assist DP operator to stay vigilant and to be aware of the situation. Therefore, the DP-RI tool turns out to be a reliable tool for different operation modes and the operator can key in their inputs to evaluate and understand the actual reliability condition of DP system.

Decision Making Capability: The DP operator could simulate the above scenario with the DP-RI tool. As shown below in the screen shot from the DP-RI tool, a software bug in the DP operator station will have an impact on the reliability of the DP control system which in-turn affect the overall reliability of the DP system. As the vessel is DP 3 class, the DP-RI is 65 % and the operator would have considered the alternative for such scenarios to prevent the incident from leading to vessel movement of 24 m. This clearly shows that the decision-making capability of DP operator increases by simulating the condition using DP-RI tool and taking precautionary steps preventing the incident from happening.



CASE STUDY NO: 2

UNAVAILABILITY OF DGNSS POSITIONING SYSTEM AND ENTERING 500M ZONE INCREASING RISK

IMCA Accident Database Case 1542: Unavailability of both DGNSS positioning units.

Primary Cause: Position Reference system – Loss of DGNSS signals was identified.

Secondary Cause: Human Error was identified.

Actual Incident Scenario: There was no position signal available from DGNSS for the DP operation. The DP operator was unaware of the situation which lead the vessel to enter the 500m zone where operation of DP Mode with position reference system is mandatory. In this incident, the major source of failure is from Human operation error, but it is due to the fact that the operator did not have clear guidance about the unavailability of DGNSS signals. This incident highlights the ignorance of DP operator and there was no clear guidance / check sheet for him to take decision before entering 500m zone. Although DP operation manual have necessary information about such failures, it becomes vessel owner responsibility to highlight criticality and importance regarding these signals during a critical or complex marine operation.

PROPOSED DP-RI DECISION MAKING TOOL:

Situation Awareness: This case clearly indicates that the DP operator was unaware of the situation. It is industry practice that before any DP operation, it is responsibility of DP operator to ensure that all the critical systems are available. From the failure report, it is evident that both the DGNSS positioning unit part of the reference systems are not available. Under such circumstances, the DP operator should have never enabled the vessel in DP mode for operation into 500m zone as there is a greater risk that could lead to an accident. The advantage of DP-RI tool in this case, is that it would have presented the situation with much more clarity than any other documentation available on-board. Such tool can also be part of the DP operator daily routine checks and work process which enables them to understand a failure of that nature during complex marine operation thereby helping them with guidance and decision making process.

Decision Making Capability: It is possible for the DP operator to simulate the above scenario with the DP-RI tool. As shown in the screen shot below from the DP-RI tool, the unavailability of the DGNSS signals would have be easily identified by operator. Furthermore, the reliability index calculated by the DP-RI tool is around 50%, which is a clear indication of a low reliable condition and the operation could have been stopped to find a solution before entering the 500m zone. Thus, the tool, enlightens the DP operator in determining the reason for the low reliability value and provides suggestion to enable the third independent position reference signal before starting the operation.

